Deciphering redox conditions, solute sources and carbon cycling of Mesoproterozoic Ocean from trace element, REE, C, O, Sr and Nd isotope proxies of carbonate rocks

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The Mesoproterozoic Era (1.6 – 1.0 Ga) has long been considered a period of relative stasis in Earth's environmental evolution. The extreme low diversity of life and relative stasis of carbon cycle (uniform $\delta^{13}C$ ~0 ‰ in marine carbonate) are thought to be related to low oxygen levels in the atmosphere (0.1% PAL) and ocean [1]. But, in view of tectonic control on oxygenation and global C-cycle [2], and the well established fact of assembly of two major supercontinents (Columbia and Rodinia) during Mesoproterozoic, such a stasis is intriguing and possibly reflects gap in data.

We have carried out a high-resolution trace, rare-earth elements, C-O, Sr-Nd isotopic study on drill-core samples of carbonates of ~1.4 Ga Bhima Group, Eastern Dharwar Craton, India. Sedimentological data of Bhima carbonates (BC) show deep-water subtidal deposition, in two cycles. The typical micritic texture and low Mn/Sr ratios (~1.2) reflect preservation of primary depositional signature. BC display typical seawater-like patterns with uniform HREE enrichment (Nd/Yb_{SN}~0.52), high Y/Ho ratios (~37) and high-frequency variations of $\delta^{13}C$ ranging from -1.0 to +3.9. The Ce/Ce* (0.84 ± 0.12) data indicate well-oxygenated seawater, with localised anoxic intervals, which correlates well with negative $\delta^{13}C$ excursions. Our finding suggests that oxygen deficiency was linked to C-cycle and much stronger biological pump during the Mesoproterozoic.

BC show high $^{87}Sr/^{86}Sr$ ratios (0.707-0.712) compared to contemporary seawater (0.705) and much radiogenic $\varepsilon Nd_{1.4Ga}$ (-6.2 to 1.9) compared to that of Dharwar Craton (-15). This indicates dominant solute sources were from a juvenile continental arc, with a minor component from the Dharwar craton. Time-series of $^{87}Sr/^{86}Sr$, $\delta^{18}O$ and εNd_t show mutual correlation, and intervals of lighter $\delta^{18}O$ – high $^{87}Sr/^{86}Sr$ – negative εNd_t indicate enhanced run-off from old Dharwarian crust. We infer tectonic control on C-cycle and solute-fluxes, and suggest that Bhima basin opened as an extensional basin behind a continental arc.

[1] Planavsky et al. (2014) *Science* **346**, 635-638.
[2] Lee et al. (2016) *Nature Geoscience* **9**, 417-424.